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ABSTRACT

This paper discusses a longitudinal, exploratory study of developmental dimensions related to object permanence theory and explains how multidimensional scaling techniques can be used to identify developmental dimensions. Eighty infants, randomly assigned to one of four experimental groups and one of four counterbalanced orders of stimuli, were tested at 4 and at 8 months of age. Each group was tested on six cloth hiding tasks spanning several stages (18 trials) and seven with-occlusion and without-occlusion tracking tasks. The four experimental groups, differing in how much information about the object was available, were Regular, Sound, Intermittent Sound, and Control. Infants were ordinally assessed from videotapes with adapted measures designed to make haptic and visual assessment parallel. One way analysis of variance revealed significant differences in performance both among and between experimental groups. Guttman scales were obtained for all groups except the control group. Use of non-metric techniques revealed that the task items did not scale as predicted in traditional object permanence theory. Additional statistical techniques were used to test a Piagetian object permanence dimension interpretation. These techniques showed that individual differences were not important. A Piagetian interpretation was not supported. It is concluded that the multidimensional scaling approach is useful, with qualifications, and can be used to supplement traditional pass/fail Guttman scales. (Author/RH)

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A MULTIDIMENSIONAL SCALING APPROACH TO DEVELOPMENTAL DIMENSIONS IN OBJECT PERMANENCE AND TRACKING STIMULI

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There are two purposes of this paper. First, to explore some methods of studying developmental dimensions and, second, to study the antecedents to successful object permanence solution. Although in 1973 Wohlwill listed the identification of developmental dimensions as a major and initial task of developmental approaches to behavior, only a very few data studies have attempted to undertake this task. Perhaps the reason for this gap involves the limited knowledge that many of us have about techniques appropriate to our particular concerns.

Non-metric multidimensional scaling (MDS)--a form of statistical procedure which reveals the structure among non-metric multivariate data--is especially applicable as a solution to several of these difficult developmental problems. First, in Piagetian research in particular, our measures of development and of performance usually are qualitative and ordinal rather than quantitative. Furthermore, linear models of development may be inappropriate to Piagetian theory (Uzgiris, 1976). Even when measures are quantitative, nonlinear models may be preferrable. Next, Piagetian theory, as well as general developmental theory, indicates we should examine both the multivariate patterns of an individual's responses to various tasks and the way these patterns change over time (Flavell and Wohlwill, 1969).

Finally, because MDS will reveal the structural relationships among data, it can uncover nonlinear dimensions of development. Guttman scales,

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although appropriate for ordinal data and sometimes a first step, cannot indicate whether there is a "universe of content". Guttman scales can indicate skills develop in some invariant sequence within individuals, but not whether the sequence itself involves skills that are meaningfully related to each other. The present paper, therefore, discusses some relevant data and explains how techniques related to multidimensional scaling can be applied to the problem of identifying developmental dimensions.

Object permanence is a good content area for initial exploration of the problems of studying developmental dimensions. This is the case because object permanence is an important but relatively circumscribed domain which has been well-researched. Furthermore, researchers agree on many of the appropriate stimuli and methods of testing.

The present research was designed to test several questions both about the existence of any developmental dimensions and, more specifically, the existence of dimensions expected in terms of object permanence theory. To test the existence of any developmental dimensions, I used Wohlwill's four criteria for identifying developmental dimensions. The first two of these criteria are logically prior to the second two and, therefore, must be tested first. These two criteria are: 1) responses form a homogeneous and unidimensional set within and across ages, and 2) the dimension is situationally-independent enough that different situations don't change the form and direction of development. The longitudinal design of the present study addressed both criteria for defining developmental dimensions, age and situational independence, by varying both age and experimental condition. His second two criteria, age changes along the dimensions and relation to developmental processes, were to be addressed if the first two criteria were satisfied.

Furthermore, I wished to test whether, as might be expected given early Piagetian theory (Piaget, 1954), object permanence items formed a unidimensional domain, whose items scaled in conformity with Piaget's substages. If no such unidimensional domain occurred, as postulated in more recent formulations of Piagetian theory (e.g., Pinard and Laurendau, 1969; Flavell and Wohlwill, 1969), at least one object permanence dimension whose items scaled in conformity with Piaget's substages was expected. Method: Eighty infants (predominantly lower-middle class and about half boys) randomly assigned to one of four experimental groups (20 per group) and one of four counterbalanced orders of stimuli were tested at 4 and again at 8 months of age. Small, attractive, mutually discriminable toys were randomly assigned to each child.

Each group was tested for all six cloth hiding tasks spanning several stages (18 trials) and all seven tracking tasks. Thus, there were 25 tasks in all. Several tracking tasks were adapted from Bower's work (Bower, Broughton and Moore, 1971). Of the cloth tasks, nine were visible displacement problems (object under one cloth, under one of two cloths--i.e., the AB task, successively under one of three cloths) and nine were invisible displacement problems (under one, under one of two, successively under one of three cloths). The multiple tasks of each type involved controls for position biases (e.g., center versus side for trials using one cloth). The third trial of two cloth problems was the B trial. The various controls are described in Miller, Cohen and Hill (1970). A box was used for invisible displacement tasks. The tracking tasks included tasks both with occlusion behind the barrier (i.e., object disappears and reappears, disappears without reappearance, disappears and new object reappears), and

without occlusion (i.e., moving object disappears at end of trajectory--a control for the barrier task, Stage II tracking, Stage III tracking, object slowly stops in view).

Presentation of cloth permanence tasks generally followed Miller, et al (1970). Tracking tasks generally followed Bower et al (1971). Speed of the object on the track was 5.3 in./sec., occlusion time behind the barrier was 3 secs., and the barrier was 16 in. wide. Sound cues on the track were eliminated. The distance of the infant from the barrier was 7 in., so that the infant had to turn to see the object on the other side and could not spy the others out of the corner of his/her eye while focusing on the first edge of the barrier or looking straight ahead.

The four experimental groups differed in how much information about the object was available. In three of the groups, the object was visually hidden during appropriate portions of the barrier and object permanence tasks (e.g., behind the barrier in tracking tasks, and under the cloth and in the box which was used for invisible displacement in cloth permanence tasks). The first group, Regular, paralleled Piaget's traditional test situation, that is, no sound emanated from the object. In the second group, Sound, sound (xylophone tune) came out of the object throughout each task. In the third group, Intermittent Sound, the xylophone tune continued to emanate from the object only while the object was in view. This condition was designed to parallel visual information during Piaget's traditional barrier and permanence tasks, for which view of the object disappears during hiding. In the fourth group, the Control group, the object was never hidden from the infant's view. Otherwise, trials in all groups duplicated those in the Regular group.

Kruskal-Wallis one-way analysis of variance showed that there were significant differences in performance (number of tasks passed) both among experimental groups and between experimental and control groups (Townes-Rosenwein, 1977). Significant differences among groups, of course, are important in order to establish that the groups chosen for study are situationally different enough to provide an adequate test of the situational independence of developmental dimensions.

The infants were scored from videotapes. The level of performance was ordinally assessed. The measures (adapted from Uzgiris and Hunt, 1975; Nelson, 1971; Bower et al., 1971) were designed to make haptic and visual assessment parallel. Correlations among scores showed that this parallelism was achieved--correlations were higher between visual and haptic assessment of the same task than for same modality assessment of two different tasks.

Results: First, Guttman scales were applied to pass/fail data of Piaget's object permanence scale where the criterion for passing was passing each task of the same stimulus type (Stage II, Stage III, one cloth with visible displacement, two cloths with visible displacement, three cloths with visible displacement, one cloth with invisible displacement, two cloths with invisible displacement, three cloths with invisible displacement). As expected, Guttman scales (Guttman coefficient of reproducibility of .9 or above, Green's index .5 or above) were obtained for all groups except the Control group. This was true when all tasks were measured within one modality, as well as when the traditional modalities of assessment were used: visual for tracking items and haptic for cloth items. The data satisfied the criteria for scaling less frequently when the criterion for passing was passing only

some items of a given stimulus type. Thus, these data compare to the traditional findings in object permanence studies about Guttman scales.

Then, various non-metric techniques, developed principally by James Lingoes at the University of Michigan (1972, 1973, 1977a) were applied to the dimensional question. First, a multidimensional scaling (SSA-I using a Euclidean metric)of similarity data was performed. In such analyses, the program takes the similarity ratings among tasks and places them into a space with the smallest orthogonal dimensionality it can. In the plots of the resulting configuration of space, points that are relatively more similar to each other are closer together, those that are different from each other are further apart. Infants this young obviously could not directly rate the similarity between pairs of tasks. Therefore, correlations (Kendall tau b) between levels of performance on every pair of tasks were used as indirect similarity data.

The results from analyses of all 25 tasks together (using the traditional modalities of assessment: visual measures for tracking tasks and haptic for cloth permanence tasks) revealed four orthogonal dimensions for each age and condition. The items didn't scale as predicted in traditional object permanence theory. The space still was multidimensional and didn't reveal a traditional permanence scale, when data included various stimuli (e.g., only cloth items, only Piagetian items) both ages, or both modalities on all stimuli.[1] The same results occurred when only eight tasks were analyzed, as in the Guttman scales, and passing equalled similar performance on each trial within a stimulus type.

In addition to visual examination of the configuration plots, the interpretation of the dimensions was approached in three ways. First, I used

a hierarchical cluster technique for ordinal data which also incorporates significance criteria (PEP-I) to determine whether individual differences contributed differently to the solution. If the infants had had longer attention spans, I could have performed several replications of each item and analyzed each infant separately using the PINDIS technique described below. Second, I placed interpretative vectors through the space (CM-V) to see how much variance each explained. These sorts of procedures are particularly important when the space is not easy to visualize (i.e., the number of dimensions is greater than three). Third, I constrained the solution to various interpretations (CONSCAL--see Noma and Johnson, 1977a, 1977b) and measured the change in stress (Stress is the measure of how well the data fits into the space). This latter procedure gives an indication of whether, in the original plots, the deviations from your interpretation are important. In addition to the post hoc interpretations, I tested a Piagetian object permanence dimension interpretation.

These techniques showed that individual differences were not important. A Piagetian interpretation wasn't supported, while similar dimensions appeared at both ages and in all conditions. The results for the Regular condition using traditional modalities of assessment, the condition and modalities of assessment most critical for Piagetian theory, are presented in Table 1 and Figures 1 & 2. Explanation for the labels in Figures 1 and 2 precedes the figures.

Thus, Table 1 shows that several gross distinctions among the items (e.g., whether or not the item contains three cloths, is a tracking item, includes the box) account for a large portion of the variance at both 4 and 8 months. CONSCAL results showed that, of these, dimensions 1 through 3 at 4 months and 1 & 2 at 8 months were consistent with constraint and increased the stress

very little. Thus, for both ages tracking items and three cloths were important distinctions. In addition at 4 months, box items were especially distinctive. A tracking dimension also occurred when all tasks were measured by both modalities. Thus, the tracking dimension was not just a result of the modality measured.

Figures 1 and 2 show visual plots of the configurations obtained at 4 and 3 months. Each plot represents one slice through the four-dimensional space. Visual interpretation is hazardous and only a first step, when the solution contains more than three dimensions. However, as an example of visual examination of the plots, you can see that, at 8 months, items containing three cloths tend to be on one side of Dimension 1. Thus, in Figure 2 these items are over to the right in plots 1 through 3 (at the top of the page).

To answer Wohlwill's questions about age and situational independence of the developmental dimensions, the spatial configurations were compared with each other (across conditions and between ages). This procedure could indicate whether the relations among the stimuli and, further, the dimensions themselves were similar. First, comparisons of mean Kendall taus of the derived distances (from the SSA-I's) showed no significant similarity.[2] Second, PINDIS (Lingoes and Borg, 1978; Lungoes, 1977b) also showed little initial similarity among configurations before weighting (only 10% variance was explained). PINDIS is a technique comparing configurations for dimensions and/or variables both after isometric transformation (i.e., transformations that <u>don't</u> change relative distances among points) and then after weighting (those that <u>do</u>). Weighting showed that the dimensions, rather than the placement of variables on dimensions were similar (55-60% variance explained--a "good" result for four dimensions).

Discussion and Conclusions:

What can one conclude about developmental dimensions? Wohlwill's criteria of age and situational independence of dimensions apparently occurred. Wohlwill's second two criteria--age changes along dimensions and relation to developmental processes--applied to the dimensions taken as a superordinate group. As a group, the dimensions appear to involve gross categorizing in which one sensory motor characteristic is singled out as a basis for similarity and all items not possessing this characteristic are considered different. The distinctions the infants are making cannot be logical, since items of very different logical types are grouped together and, furthermore, these groups include items that are passed at very different points in development. Rather, the infants' behavior appears to be a primitive and imperfect type of categorizing. It is the earliest form of categorization previously found. Other studies have reported it in any frequency, only in infants at least one year old (Fenson, Kagan, Kearsley, and Zelazo, 1976; Nelson, 1973; Riccuiti, 1965). However, in the present study, several aspects of the situation probably decreased the difficulty of categorizing and/or encouraged its appearance; for instance, goal orientation and familiarity with similar problems at home[3] (Wright and Vliestra, 1975; Wright, 1977), and the fact that the task did not involve the simultaneous presence of several tasks. For the superordinate group, age changes along the dimension involve increased coordination among characteristics used to categorize the items and increasingly sophisticated categorization behavior. Little coordination was apparent in the spatial configuration at 4 months. By 9 months, there were some examples of non-orthogonal dimensions which involved the same kinds of gross distinctions. This superordinate group also has obvious implications for developmental processes. In fact, in

other content areas, similar developmental changes frequently have been proposed (e.g., Piaget and Inhelder, 1967; Vurpillot, 1976).

Thus, all of Wohlwill's criteria have been satisfied and developmental dimensions found; these do not conform to Piagetian object permanence theory. Further hypothesis testing must determine whether categorization dimensions can be reliably found. However, if they are, the data indicate that, even in the Stage II-III period, categorization has important implications for understanding how children approach and perceive problem-solving situations like object permanence. In addition, perhaps the perceptually and motorically based categorizations will facilitate logical distinctions at some later date.

Although the MDS approach has been useful and supplements the traditional pass/fail Guttman scales obtained in our data, several caveats remain. Conclusions are obviously data bound, bound by the ages tested and amount of exposure to the task, as well as by the more usual psychometric considerations like reliability. These considerations are particularly important for a qualitative theory like Piaget's. Our own data investigates homogeneities in the period before one cloth solutions are consolidated. Thus, most infants in this study had not yet reached Stage IV, even at 8 months. The perceived domain may change drastically after this consolidation. However, Piaget's original theory proposes that the tasks are related to object permanence acquisition in the same manner, regardless of the child's level of performance. Amount of exposure probably wasn't an important factor in the present experiment, since there was more than one trial per stimulus type and, in addition, tasks had considerable ecological validity.[3] Solutions also are bound by the reliability of the data. Similarity among independent solutions, as well as the retest reliability obtained by Hunt and Uzgiris (1975) for object perman-

ence assessment, indicate these data are not random. Finally, the study of major qualitative changes may be difficult in some forms of MDS analyses. However, there are ways of circumventing this drawback (Shepard, 1974). Finally, these results may not occur in all cultural contexts, although similar object permanence results are likely within western civilization.

However, many of these problems are problems for the field of developmental psychology as a whole, and not specific to the use of MDS or the problem of identifying developmental dimensions. In conclusion, while MDS provides a valuable tool for approaching questions like developmental dimensions, even in restricted and well-researched areas like object permanence, the identification of developmental dimensions will be difficult.

FOOTNOTES

1 Mehrabian and Williams (1971) achieved homogeneity with a set of items that included some object permanence items. However, they coded their items in almost all instances only for pass/fail performance, did not include all the stimulus types used in the present experiment (among other gaps there were no invisible displacement trials), and did not include more than one trial for each stimulus type.

2 This is a procedure used by Neel, Rothammer, and Lingoes, 1974 and by Lingoes, 1977a.

3 Aside from being tasks similar to events experienced at home from a theoretical point of view, parents in the study reported that the babies engaged in similar situations at home.

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Table 1. Percentage of Variance of Entire Configuration (Figures 1 & 2) Accounted for by Various Interpretive Vectors - (CM-V)

% Variance by Dimension**	4 Month Olds Regular Condition	8 Month Olds Regular Condition
Tracking vs. other items	Dimension 3 - 24% (46% total variance in space*)	Dim. 2 - 28% (46%*)
3 cloths vs. other items	Dim. 1 - 19% (28%*)	Dim. 1 - 35% (48%*)
Box vs. other items	Dim. 2 - 32% (43%*)	***
2 cloths vs. other items	***	Dim. 4 - 11% (45%*)
Total % variance explained by all interpretations of dimensions	75%	74%

* Includes percentage of all four configuration dimensions.
** Dimension with highest amount of variance is reported.
*** Under 10% variance explained. Thus, no interpretation for this dimension is offered.

Explanation of the Labels in Figures 1 & 2

Cloth permanence items

C1 - one cloth, trial 1
C2 - one cloth, trial 2
CC1 - two cloths, trial 1 (side A)
CC2 - two cloths, trial 2 (side A)
CC3 - two cloths, trial 3 (side B)
CCC1 - three cloths, trial 1
CCC2 - three cloths, trial 2
CCC3 - three cloths, trial 3
CCC4 - three cloths, trial 4
CB1 - one cloth plus box, trial 1
CB2 - one cloth plus box, trial 2
CCB1 - two cloths plus box, trial 1 (side A)
CCB2 - two cloths plus box, trial 2 (side A)
CCB3 - two cloths plus box, trial 3 (side B)
CCCB1 - three cloths plus box, trial 1
CCCB2 - three cloths plus box, trial 2
CCCB3 - three cloths plus box, trial 3
CCCB4 - three cloths plus box, trial 4

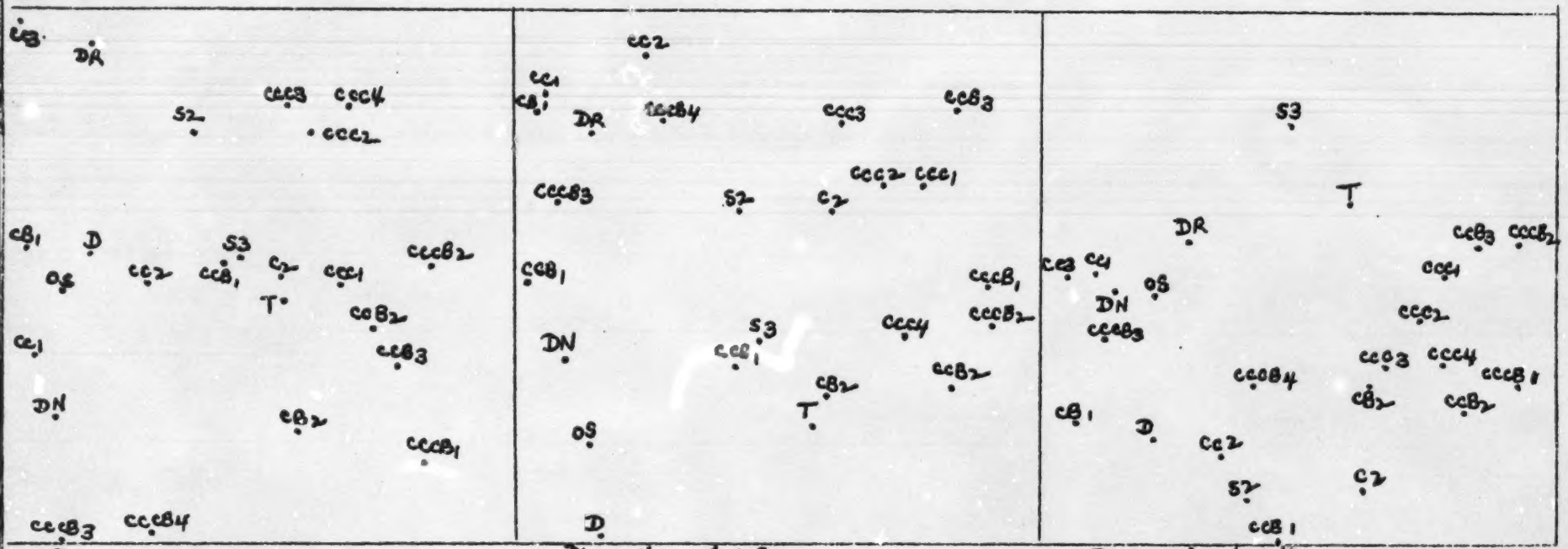
Tracking items

S2 - Stage II tracking
S3 - Stage III tracking
DR - barrier item, object disappears and reappears
D - barrier item, object disappears
DN - barrier item, object disappears and new object reappears
T - control for barrier item, object never disappears
OS - object stops in front of child

N.B.: Items C1 through S3 constitute Piagetian items related to object permanence. Items DR through OS are based on Bower's tracking items. In Figures 1 & 2, cloth items are haptically measured and tracking items visually measured.

Figure 1. Four-dimensional non-metric similarity solution (SSAI) for 4 month olds in the Regular condition*
(Kruskal's stress = .12, Guttman-Lingoes coefficient of alienation = .13)

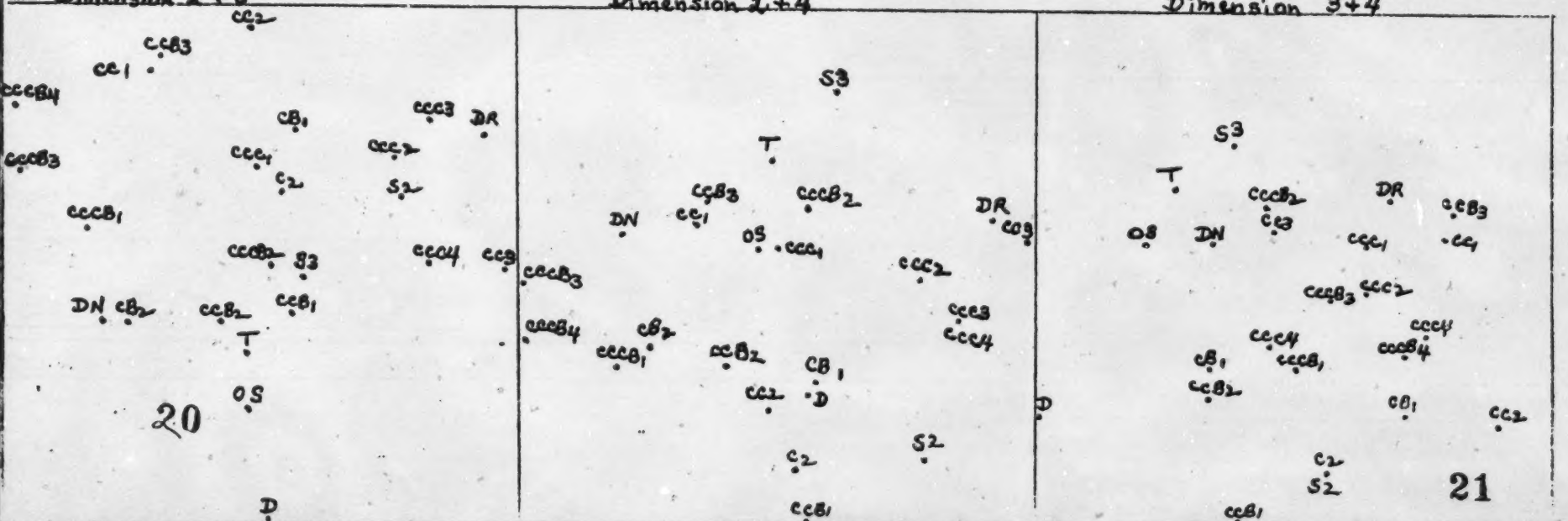
P.3



Dimension 1 + 2 | Dimension 1 + 3 | Dimension 1 + 4

*N.B.: origine and rotation of axes are arbitrary, although rotated to a principal component solution. C1 was eliminated from analysis, because it was a constant.

Dimension 2 + 3 | Dimension 2 + 4 | Dimension 3 + 4



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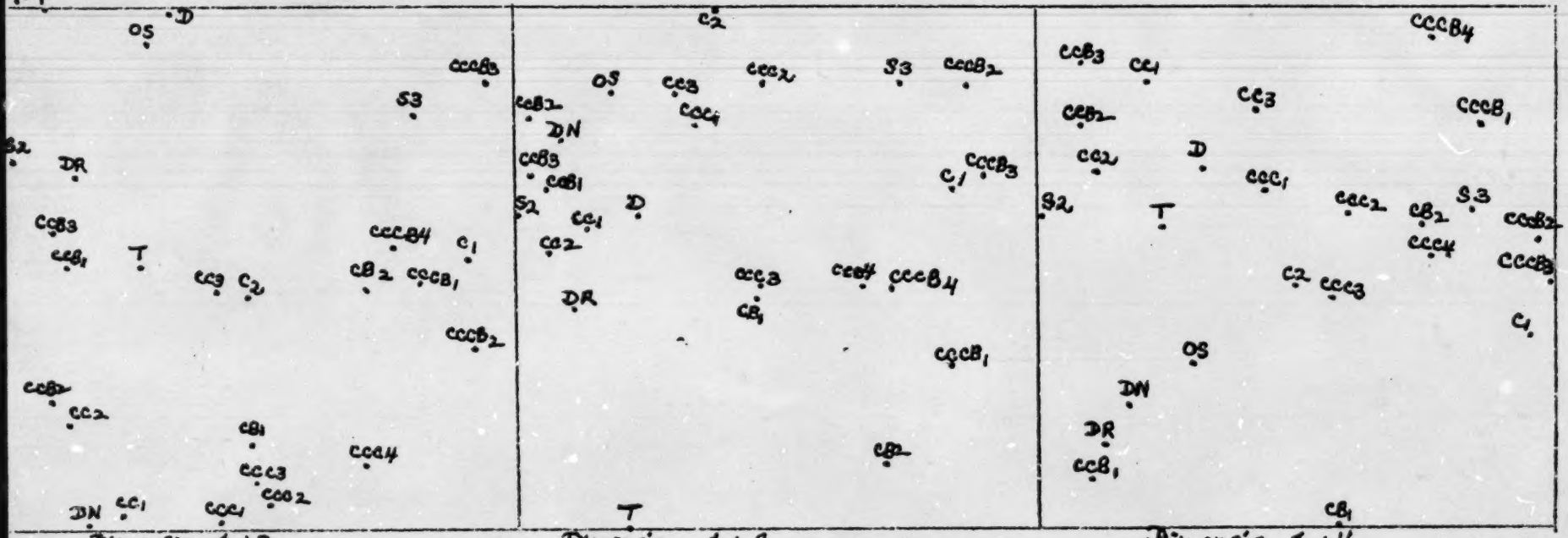
21

Figure 2. Four-dimensional non-metric MDS similarity solution (SSA-I) for 8 month olds in the Regular condition *
(Kruskal's stress = .12, Guttman - Lingoes coefficient of alienation = .13)

P.4



*N.B.: Origins and rotation of axes are arbitrary, although rotated to a principal component solution.